SITE SELECTION FOR THE MGS '01 MISSION: AN ASTROBIOLOGICAL PERSPECTIVE.

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Introduction: Major goals of the Mars Global Surveyor Program include: 1) the search for past or present life, and/or evidence of prebiotic chemistry, 2) understanding the volatile and climatic history of Mars, and 3) determining the availability and distribution of mineral resources. The cross-bridging theme for these goals is the history of liquid water. Among the most important objectives of the MGS program is to visit sites that have a high priority for exopaleontology-- that is, to explore sites that have a high potential for harboring a Martian fossil record and/or prebiotic chemistry. Studies of the terrestrial fossil record reveal that microbial fossilization is strongly influenced by the physical, chemical and biological factors of the environment which together, strongly influence the types of information that will be captured and preserved in the rock record. On Earth, the preservation of biogenic signatures in rocks basically occurs in two ways: rapid burial in fine-grained, clay-rich sediments and rapid entombment in fine-grained chemical precipitates. Entombment by aqueous minerals can occur as either primary precipitates (e.g., hydrothermal sinters, or evaporites), or during early diagenetic mineralization (e.g., cementation). The key process is the rapid reduction of permeability following deposition. This creates a closed chemical system that arrests degradation (oxidation). For long-term preservation, organic materials must be sequestered within dense, impermeable host rocks composed of stable minerals that resist chemical weathering, dissolution and extensive reorganization of fabrics during diagenetic recrystallization. Favorable minerals include highly ordered, chemically-stable phases, like silica (forming cherts) or phosphate (forming phosphorites). Such lithologies tend to have very long crustal residence times and (along with carbonates, shales), are the most common host rocks for Precambrian microfossils on Earth. Other potentially important host rocks include evaporites and ice, both of which have comparatively short crustal residence times on Earth. These "taphonomic" constraints provide a fairly narrow set of criteria for site selection. While they are difficult to apply in the absence of mineralogical information, their consideration is nevertheless essential if we are to follow a strategy founded in clear scientific principles.

Scientific Constraints for Site Selection: A key objective of MGS is to identify sites for exopaleontology and then collect samples for return to Earth. Certainly a first step in the process is to target sites where liquid water was present and could have provided a clement environment for life. Next is to identify sites where aqueous sediments were deposited. However, the fact that microbial fossilization only occurs under specific circumstances means the site selection process cannot end with these broad criteria. On Earth, most aqueous sedimentary deposits are actually barren of fossils. Thus, the second step in the process involves identifying those paleoenvironments that were most favorable for the capture and preservation of fossil biosignatures (as noted above). Based on terrestrial analogs, geological environments that are especially favorable for preserving a microbial fossil record include [1,2]: 1) mineralizing hydrological systems (e.g., surface and shallow subsurface hydrothermal, mineralizing cold springs in alkaline lake settings), 2) evaporite basins (e.g., terminal lake basins and arid shorelines), and 3) mineralizing soils (e.g., sub-soil hard pans including silcretes, calcretes and ferracretes).

Engineering Constraints for Site Selection: The 2001 lander will be deployed by parachute and use a retro-rocket landing system similar to Viking. This will constrain landing site elevation to between +2.5 and –3.0 km, and surface rock abundance to between 5-10%. Because the lander will be powered exclusively by solar panels, sites are also limited to equatorial latitudes between 3^{o}N and 12^{o}S. Finally, it has been suggested that, if possible, sites be limited to those that are covered at Viking resolution better than 50 m/pixel. This last constraint places an especially severe limitation on the number of scientifically-interesting sites for Astrobiology. However, this constraint, along with the rock abundances estimated by IRTM, can be relaxed for sites where supplemental high resolution MOC imaging can be obtained (http://mars.jpl.nasa.gov/2001/landingsite/EngConstr.html).

Approach Used: Using composite maps showing the distribution of the above constraints provided by JPL (http://mars.jpl.nasa.gov/2001/landingsite/EngConstr.html) we have reviewed all Viking imaging data for sites that meet the engineering constraints defined above. Each site has been visually examined at the highest Viking resolution available and prioritized according to the following scheme:

Highest priority: Evidence for varied and sustained hydrological activity; sites where water may have ponded (potential terminal lake basins with evaporites or fine-grained detrital sediments, inclusive of impact craters); chaos areas or channels adjacent to volcanic edifices or impact craters (potential hydrothermal mineralization); floors of impact craters with central peaks and associated high albedo features (potential hydrothermal activity and/or evaporites or fine-grained detrital deposits); with pristine features, deflational areas showing little or no evidence for aeolian mantling.

Moderate to high: As for high, but with aeolian mantling evident as isolated dunes.

Moderate priority: Termini or floors of channels (potential grab-bag sites) that originate in highland chaos or adjacent to volcanic edifices (areas of potential hydrothermal mineralization); evidence of general terrain softening due to aeolian mantling or surface weathering, although features still visible.

Low-moderate priority: Evidence of isolated hydrological activity as sparse channels located in intercrater highland areas (potential grab-bag sites?). Heavy to moderate aeolian mantling.

Lowest priority: No evidence of hydrologically-related geomorphic features (e.g., extensive lava flows or pyroclastics), and/or heavily mantled (or otherwise featureless) terranes.

Results: Within the engineering constraints outlined above, Table 1 presents the results of our preliminary global reconnaissance of potential landing sites for exopaleontology. The overall impact of the Viking resolution requirement (50 m/pixel) and strict adherence to rock abundance data eliminated all but one of the highest priority sites we had identified previously, based only on elevation and latitude constraints (Table 2). While a number of moderately-high priority sites remain (Table 1), clearly the highest priority (most scientifically compelling) sites for Astrobiology lie outside of the Viking resolution requirements or are marginal in terms of rock abundance.

TABLE 1. High to moderately-high priority sites for Astrobiology. Sites identified meet all engineering constraints (within 3°N-12°S; rock abundance 5-10%) and Viking Orbiter Imagery at <50 m/pixel.

Site Name	Latitude/Longitude	Site Type	VO Image Coverage
HIGHEST PRIORITY			
Terra Cimmeria	8-11°S 216-220°W	1, 2	760A01-12
Mangala Valles	3-12°S 150-155°W	1, 2	442S-460S image series
MODERATE TO HIGH PRIORITY			
MC-11			
Xanthe/Da Vinci crater	0-3°N 40-44°W	2	742A01-66
S. Ares Vallis	0-3°N 17-19°W	2	405B19-40
MC-13			
Libya Montes	1-3°N 272-274°W	1, 2	137S02-24
MC-19			
SE Xanthe/Iani Chaos	9-12°S 27-29°W	3	962A21-29
SE Xanthe/Iani Chaos	9-12°S 29-30°W	3	963A21-30
SE Xanthe/Iani Chaos	8-12°S 30-31°W	3	964A21-30
Iani Chaos	0-3°N 13-15°W	3	406B01-18
MC-23			
Apollinaris Chaos	12-4°S 188-190°W	3	372B01-26
NE of Gusev crater	14-9°S 180-181°W	1, 2	386B01-26
Al-Qahira Vallis	15-14°S 194-196°W	1, 2	452A01-08

TABLE 2. High to Moderately-High priority sites nearly meeting present engineering constraints (within 3°N - 12°S), marginal rock abundance, and Viking Orbiter Imagery ~50 to 100 m/pixel.

Site Name	Latitude	Longitude	Site Type	VO Image
HIGHEST PRIORITY SITES				
Amenthes Rupes	2.9°S	249.5°W	1, 2	379S45, 47
Apollinaris "chaos"	11.1°S	188.5°W	2, 3	596A35-36; 635A57
Da Vinci crater	1.2°N	39.1°W	2, 3	014A72-80
Ganges Chasma (1)	8.5°S	43.9°W	1, 2	014A29-41
Ganges Chasma (2)	8.8°S	42.5°W	1, 2	014A29-41
Libya Montes (region)	1-3°N	270-280°W	1, 2	377S75-80; 876A02-05
N Memnonia Terra (1)	11.3°S	174.2°W	1, 2	38S10-14; 439S03-09; 440S02-08
N Memnonia Terra (2)	11.2°S	178.2°W	1, 2	437S07-09; 438S02-05
Nicholson crater	0°	164°W	2, 3	387S31-34; 637A47-50
Reuyl crater	9.9°S	192.8°W	2, 3	596A31-34
Shalbatana source (1)	0.2°N	46.3°W	1, 2, 3	897A33-36, 66, 68
Shalbatana source (2)	0.7°N	44.5°W	1, 2, 3	897A33-36, 66, 68

Key for Site Types

1 = grab bag site
2 = fluvial-lacustrine
3 = potential hydrothermal

Conclusions and Recommendations: The Mars Observer Camera (MOC), presently in orbit at Mars, has been providing very high resolution images (as good as 1.5 m/pixel) for selected sites on Mars. While these images are rapidly changing our view of the Martian surface, the present distribution is nevertheless quite limited. Thus, our present recommendations are of necessity based on photogeologic evidence obtained by Viking. To address the site selection concerns of Astrobiology, we recommend that there be a focus on the highest priority sites given in Tables 1 and 2. Furthermore, we recommend that these sites be specifically targeted for high resolution imaging by MOC as soon as possible, to assist in the process of site prioritization.

The most important powerful information for reconstructing paleoenvironments (and therefore the most useful information for refining site selection for Astrobiology) is mineralogy. However, because most of the orbital data obtained by the '96 mission will not be available until after landing site selection '01, it is important that there be an ongoing effort to update site priorities for sample return missions in '03 and '05. It is also important that mapping studies be carried out now at the highest priority sites using available data and that these mapping efforts be updated as new data becomes available.

The inability to identify many smaller geological features presently impedes geological interpretations and therefore the site selection process. Targeted high resolution observations by MOC are likely to significantly advance our knowledge of finer-scale geologic features, and alter our prioritization sites for 2003 and '05. The Thermal Emission Spectrometer (TES) is presently mapping the Martian surface in the mid-IR and is expected to provide important new information about global mineralogy over the course of next year. For example, during the pre-mapping phase, TES identified a large deposit of coarse-grained hematite that is suggestive of aqueous activity. Unfortunately, this type of mineralogical data is presently too limited in distribution to provide a framework for site selection. While TES will provide globally-distributed data at 3 km/pixel, there will still be a need for follow-on mapping of key sites at higher spatial resolution. This requirement will hopefully be met by the THEMIS instrument, which is to be launched in 2001.

References: [1] Farmer, J.D., D.J. Des Marais, *Lun. Planet. Sci. XXV*, 367-368, 1994. [2] Farmer, J.D. and D.J. Des Merais, *Exopaleontology and the search for a fossil record on Mars,* (in press).